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(54) **LENS BARREL INCLUDING A CORRECTION LENS TO MOVE FOR ZOOM TRACKING, AND IMAGING APPARATUS**

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This patent is subject to a terminal disclaimer.

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(30) **Foreign Application Priority Data**

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H04N 5/262 (2006.01)

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CPC ***G02B 7/282*** (2013.01); ***G02B 7/10*** (2013.01); ***G03B 13/36*** (2013.01); ***G03B 17/14*** (2013.01); ***H04N 5/23209*** (2013.01); ***H04N 5/23212*** (2013.01); ***H04N 5/23248*** (2013.01); ***H04N 5/23296*** (2013.01); ***H04N 5/2628*** (2013.01)

(58) **Field of Classification Search**

CPC H04N 5/23296; H04N 5/23209; H04N 5/23212; H04N 5/23248; H04N 5/2628; H04N 2/232; G03B 17/14; G03B 13/36; G03B 7/085; G02B 7/28; G02B 7/282; G02B 7/10

See application file for complete search history.

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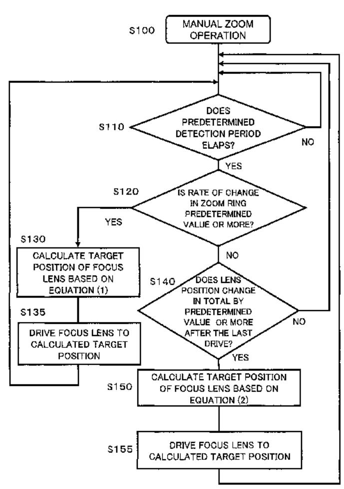
(57) **ABSTRACT**

A lens barrel includes a correction lens to move for zoom tracking, a zoom lens driver to mechanically move a zoom lens according to an amount of turn of a zoom ring, a storage unit to store relational information associating a zoom lens position with a focus position of the correction lens, and a controller to control the correction lens driver. The controller determines a focus position of the correction lens corresponding to a position distant by a predetermined amount from a detected zoom lens position, by referring to the relational information, and controls the correction lens driver to drive the correction lens to a target position set to the determined focus position. A formula varying with the change rate of the zoom lens position is used to calculate the predetermined amount, and is set according to positions of the zoom lens and the focus lens.

9 Claims, 7 Drawing Sheets



(51) **Int. Cl.**

G03B 17/14	(2006.01)
H04N 5/232	(2006.01)
G03B 13/36	(2006.01)
G02B 7/10	(2006.01)

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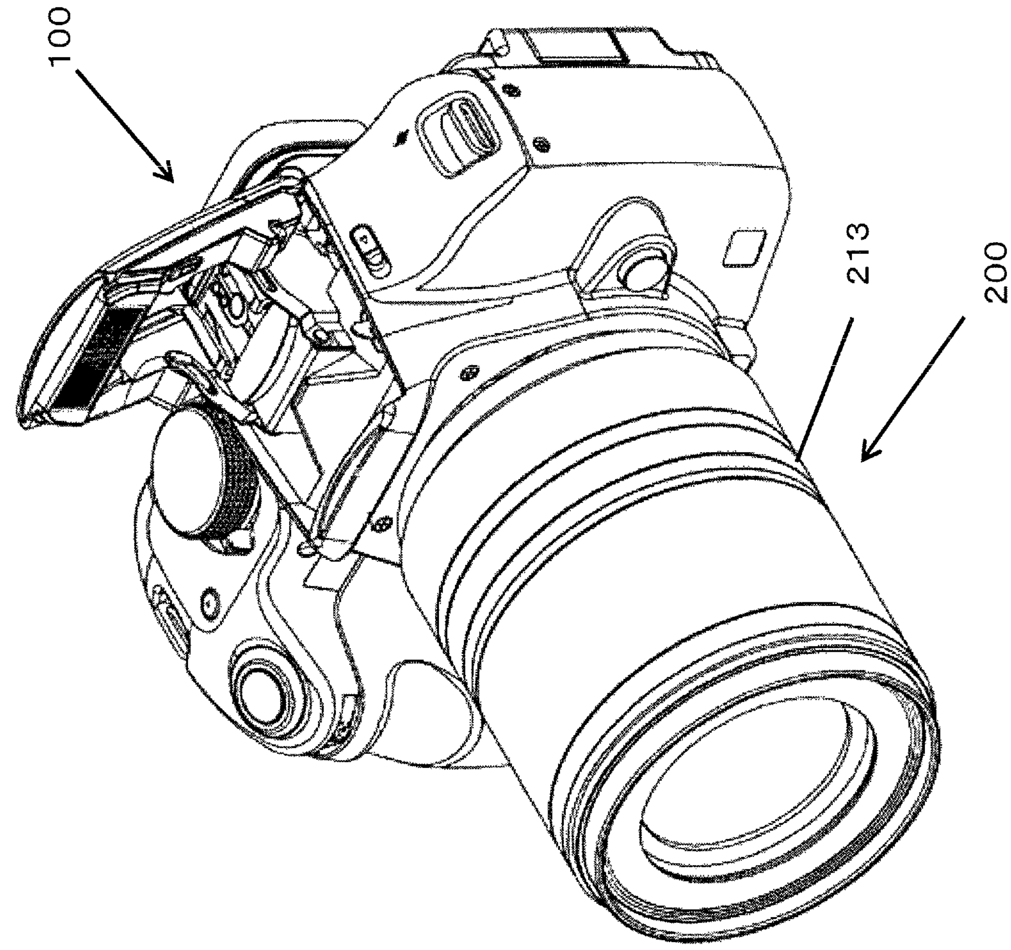


Fig. 1

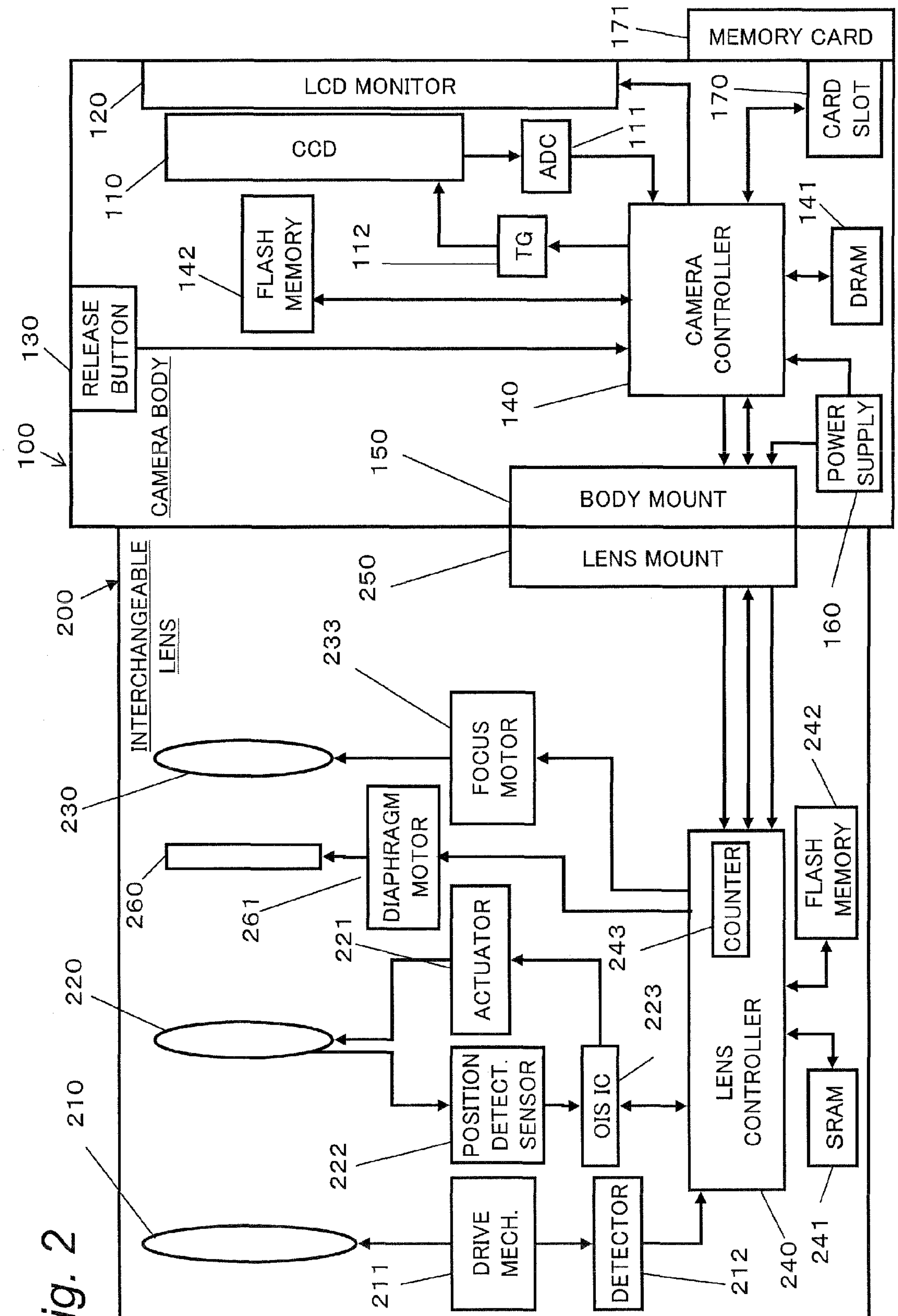
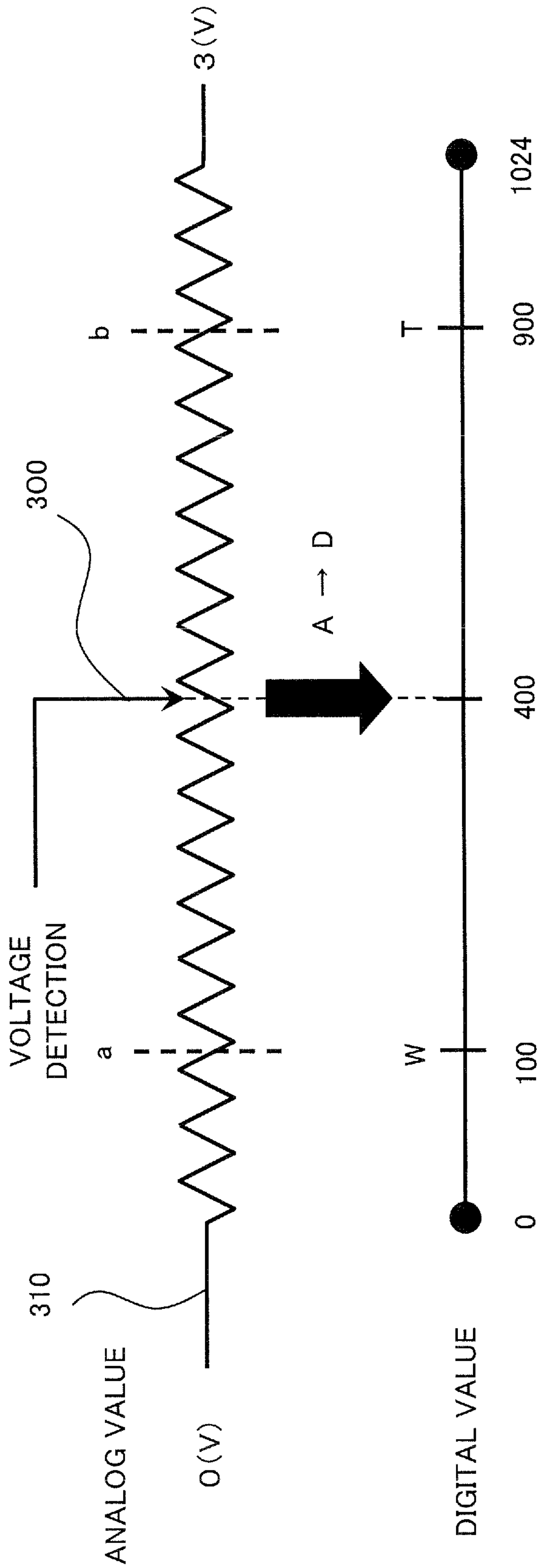

MEMORY CARD
171
LCD MONITOR
120
CCD
110
ADC
111
CARD SLOT
170
FLASH MEMORY
142
TG
112
CAMERA CONTROLLER
140
DRAM
141
RELEASE BUTTON
130
CAMERA BODY
100
POWER SUPPLY
160
BODY MOUNT
150
LENS MOUNT
250
INTERCHANGEABLE LENS
200
FOCUS MOTOR
233
230
DIAPHRAGM MOTOR
261
260
ACTUATOR
221
220
COUNTER
243
FLASH MEMORY
242
POSITION DETECT. SENSOR
222
OIS IC
223
LENS CONTROLLER
240
SRAM
241
DRIVE MECH.
211
210
DETECTOR
212
Fig. 2

Fig. 3


ANALOG VALUE
0(V)
310
VOLTAGE
DETECTION
a
300
b
3(V)
A → D
DIGITAL VALUE
0
W
100
400
T
900
1024

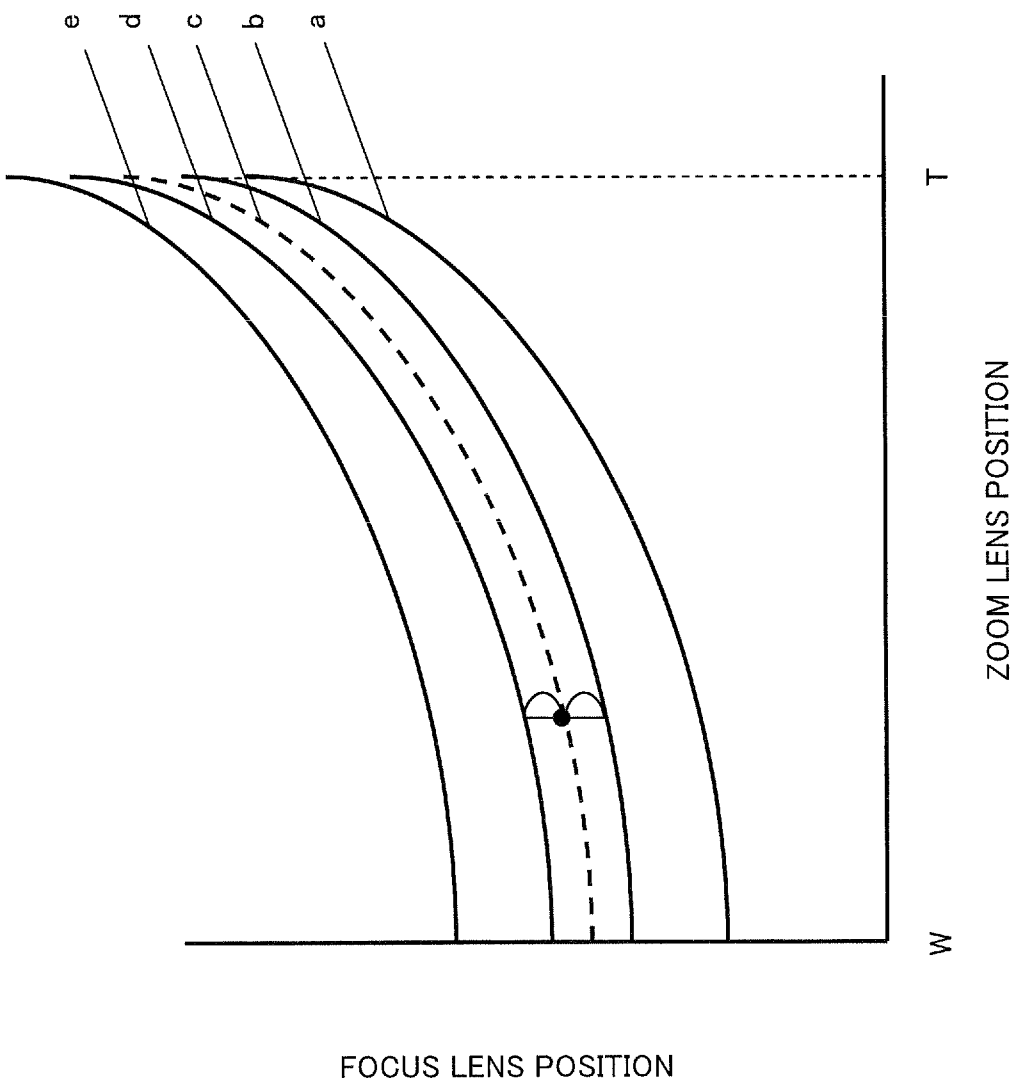


Fig. 4

Fig. 5

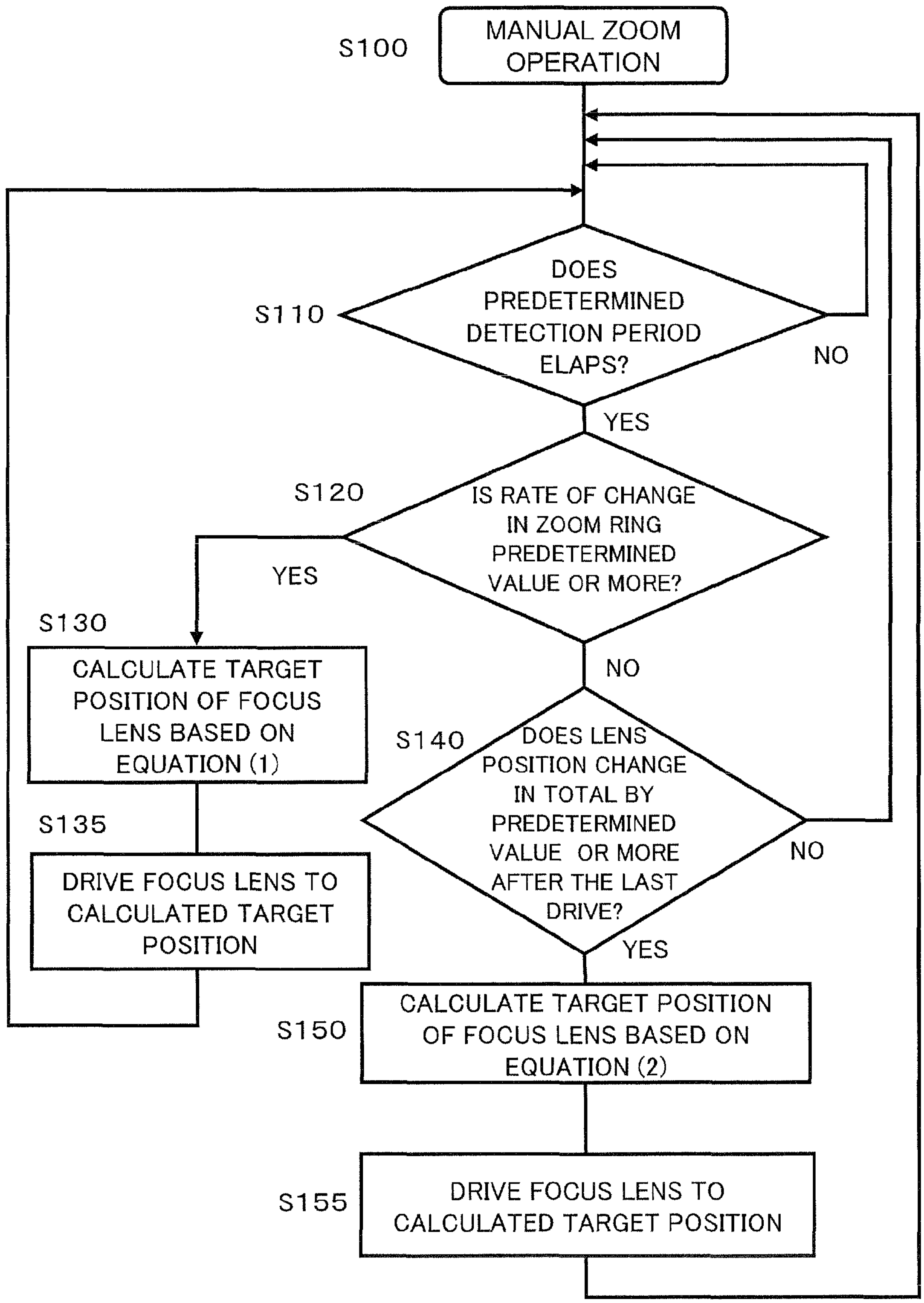

S100
MANUAL ZOOM OPERATION
S110
DOES PREDETERMINED DETECTION PERIOD ELAPS?
NO
YES
S120
IS RATE OF CHANGE IN ZOOM RING PREDETERMINED VALUE OR MORE?
YES
S130
CALCULATE TARGET POSITION OF FOCUS LENS BASED ON EQUATION (1)
S135
DRIVE FOCUS LENS TO CALCULATED TARGET POSITION
NO
S140
DOES LENS POSITION CHANGE IN TOTAL BY PREDETERMINED VALUE OR MORE AFTER THE LAST DRIVE?
NO
YES
S150
CALCULATE TARGET POSITION OF FOCUS LENS BASED ON EQUATION (2)
S155
DRIVE FOCUS LENS TO CALCULATED TARGET POSITION

Fig. 6B

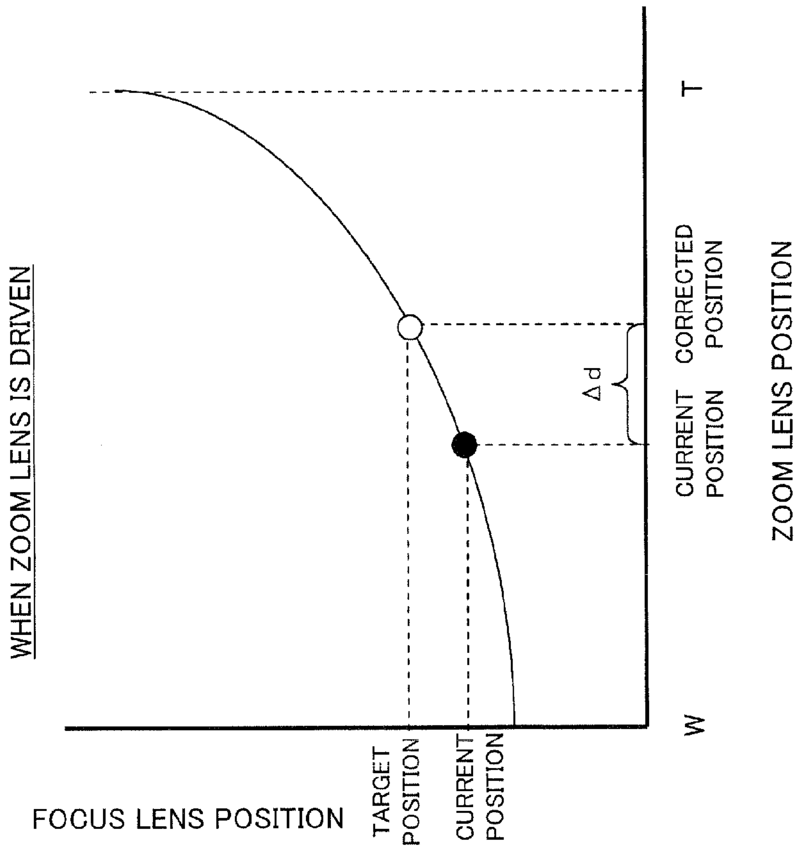

WHEN ZOOM LENS IS DRIVEN
FOCUS LENS POSITION
TARGET POSITION
CURRENT POSITION
Δd
W
T
CURRENT POSITION
CORRECTED POSITION
ZOOM LENS POSITION

Fig. 6A

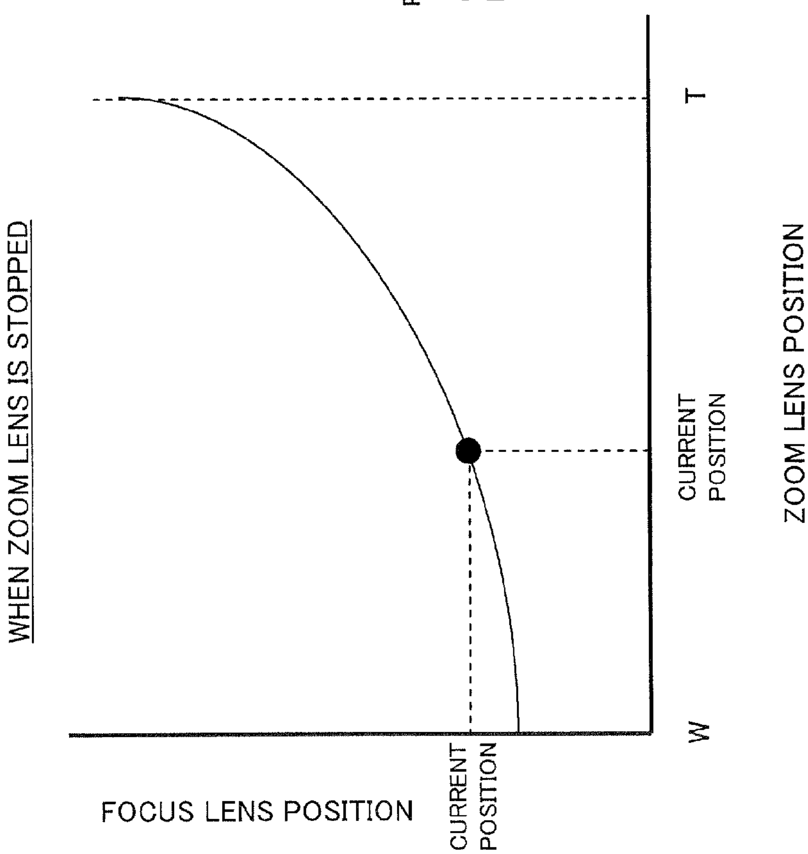
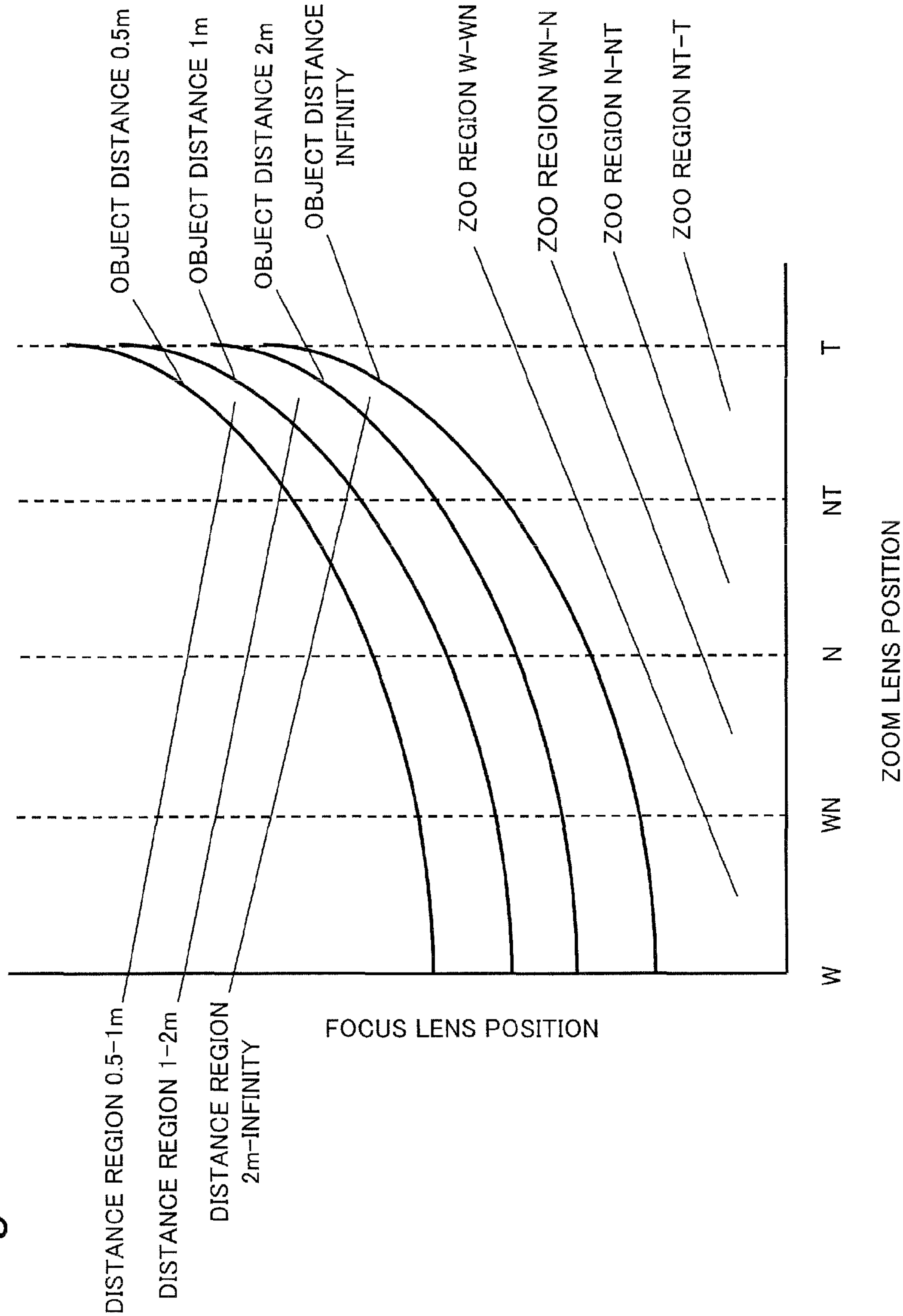

WHEN ZOOM LENS IS STOPPED
FOCUS LENS POSITION
CURRENT POSITION
W
T
CURRENT POSITION
ZOOM LENS POSITION

Fig. 7


OBJECT DISTANCE 0.5m
OBJECT DISTANCE 1m
OBJECT DISTANCE 2m
OBJECT DISTANCE INFINITY
ZOO REGION W−WN
ZOO REGION WN−N
ZOO REGION N−NT
ZOO REGION NT−T
W
WN
N
NT
T
ZOOM LENS POSITION
FOCUS LENS POSITION
DISTANCE REGION 0.5−1m
DISTANCE REGION 1−2m
DISTANCE REGION 2m−INFINITY

LENS BARREL INCLUDING A CORRECTION LENS TO MOVE FOR ZOOM TRACKING, AND IMAGING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part (CIP) application of U.S. application Ser. No. 12/555,935, with a filing date of Sep. 9, 2009, which claims priority of Japanese Patent Application No.: JP2008-233199 filed on Sep. 11, 2008, the content of which is incorporated herein by reference.

BACKGROUND

1. Technical Field

The technical field relates to an imaging apparatus such as a digital still camera, and a lens barrel mountable to the imaging apparatus.

2. Related Art

JP-A-6-153049 discloses an autofocus apparatus capable of performing zoom tracking in response to a manual zoom operation performed by a user. The autofocus apparatus stores in advance a plurality of zoom tracking curves. The autofocus apparatus can control the position of a zoom lens in a stepwise manner. Moreover, the autofocus apparatus determines a position to which the zoom lens is moved, based on a manual zoom operation performed by the user. The autofocus apparatus then selects one zoom tracking curve based on information about the determined position to which the zoom lens is moved. It is noted that the zoom tracking is an operation to keep a focus even if zoom operation is done after the autofocus apparatus comes into focus by moving the focus lens.

In this manner, the autofocus apparatus can prevent an erroneous selection of the zoom tracking curve, particularly resulting in rapid focus control upon zooming operation.

However, the autofocus apparatus described in JP-A-6-153049 can be applied only to a zoom tracking operation in which the zoom lens is electrically driven by a power zoom, and does not support a zoom tracking operation in when the user manually operates the zoom lens.

Generally, in a zoom tracking operation, when a zoom magnification is changed in a focus state, a focus lens or correction lens is driven according to a zoom tracking curve to keep the focus state. At that time, a control target position of the focus lens or correction lens is determined based on the current position of the zoom lens, along the zoom tracking curve. In cases where the focus lens or correction lens is driven based on the current position of the zoom lens, the zoom lens has already moved to another position and thus a focus state cannot be obtained when the focus lens or correction lens reaches the control target position. Hence, it is necessary to determine a control target position of the focus lens or correction lens by also taking into account the moving speed of the zoom lens.

Specifically, in the case of a power zoom in which the zoom lens is driven by a motor, the zoom speed is constant and thus a control target position of the focus lens or correction lens is determined by adding a constant value based on the zoom speed. In this case, a determination of a control target position is easy. However, in the case of manually performing a zoom operation by the user, the speed of turning a zoom ring by the user is not constant. Therefore, a determination of the control target position of the focus lens or correction lens is not easy.

SUMMARY

In order to solve the above-mentioned problems, there is provided a lens barrel capable of performing relatively accurate zoom tracking regardless of the speed of zooming operation when a zoom lens is mechanically driven by a manual zoom.

In a first aspect, a lens barrel is provided, which includes a correction lens operable to move along an optical axis to perform zoom tracking, a correction lens driver operable to drive the correction lens, a zoom lens, a zoom ring operable to be turned by a user, a zoom lens driver operable to mechanically move the zoom lens according to an amount of turn of the zoom ring, a position detector operable to detect a position of the zoom lens, a rate detector operable to detect a change rate of the position of the zoom lens, a storage unit operable to store relational information which associates the position of the zoom lens with a focus position of the correction lens, and a controller operable to control the correction lens driver. The controller determines a focus position of the correction lens corresponding to a position more distant by a predetermined amount from the position of the zoom lens detected by the position detector, by referring to the relational information, and controls the correction lens driver to drive the correction lens with a target position set to the determined focus position. The controller changes the predetermined amount according to the change rate of the position of the zoom lens detected by the rate detector. Further, the controller uses a calculation formula which varies with the change rate of the position of the zoom lens to calculate the predetermined amount. The calculation formula is set according to the position of the zoom lens and the position of the focus lens.

In a second aspect, an imaging apparatus including an interchangeable lens and a camera body to which the interchangeable lens is mountable is provided. The interchangeable lens includes the interchangeable lens includes a correction lens operable to move along an optical axis to perform zoom tracking, a correction lens driver operable to drive the correction lens, a zoom lens, a zoom ring operable to be turned bay a user, a zoom lens driver operable to mechanically move the zoom lens according to an amount of turn of the zoom ring, a position detector operable to detect a position of the zoom lens, a rate detector operable to detect a change rate of the position of the zoom lens, a storage unit operable to store relational information which associates the position of the zoom lens with a focus position of the correction lens, and a controller operable to control the correction lens driver. The controller determines a focus position of the correction lens corresponding to a position more distant by a predetermined amount from the position of the zoom lens detected by the position detector, by referring to the relational information, and controls the correction lens driver to drive the correction lens with a target position set to the determined focus position, and the controller changes the predetermined amount according to the change rate of the position of the zoom lens detected by the rate detector. Further, the controller uses a calculation formula which varies with the change rate of the position of the zoom lens to calculate the predetermined amount. The calculation formula is set according to the position of the zoom lens and the position of the focus lens. The camera body includes an imaging unit operable to generate image data of a subject image captured through the interchangeable lens, and a recording unit operable to perform a predetermined process on the image data and store the image subjected to the predetermined process in a recording medium.

In a third aspect, another imaging apparatus is provided. The imaging apparatus includes a correction lens operable to move along an optical axis for zoom tracking, a correction lens driver operable to drive the correction lens, a controller operable to control the correction lens driver, a zoom lens, a zoom ring operable to be turned by a user, a zoom lens driver operable to mechanically move the zoom lens according to an amount of turn of the zoom ring, a position detector operable to detect a position of the zoom lens, a rate detector operable to detect a change rate of the position of the zoom lens, a storage unit operable to store relational information which associates the position of the zoom lens with a focus position of the correction lens, an imaging unit operable to generate image data of a subject image captured through the interchangeable lens, and a recording unit operable to perform a predetermined process on the image data and store the image subjected to the predetermined process in a recording medium. The controller determines a focus position of the correction lens corresponding to a position more distant by a predetermined amount from the position of the zoom lens detected by the position detector, by referring to the relational information, and controls the correction lens driver to drive the correction lens with a target position set to the determined focus position. The controller changes the predetermined amount according to the change rate of the position of the zoom lens detected by the rate detector. Further, the controller uses a calculation formula which varies with the change rate of the position of the zoom lens to calculate the predetermined amount. The calculation formula is set according to the position of the zoom lens and the position of the focus lens.

According to the above-described aspects, a lens barrel capable of performing accurate zoom tracking regardless of the speed of zooming operation when a zoom lens is driven by a manual operation at any speed, and an imaging apparatus using the same can be provided.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a perspective view of a camera system according to a first embodiment.

FIG. **2** is a block diagram of the camera system according to the first embodiment.

FIG. **3** is a diagram for describing a method for detecting a turn speed of a zoom ring.

FIG. **4** is a diagram (zoom tracking curve) for describing a relationship between a position of a zoom lens and a focus position of a focus lens.

FIG. **5** is a flowchart showing a zoom tracking operation.

FIGS. **6**A and **6**B are diagrams for describing drive control of the focus lens when a zoom tracking operation is performed.

FIG. **7** is a diagram for describing a calculation of increase (correction amount) Δd in zoom lens position based on both the zoom lens position and the focus lens position.

DETAIL DESCRIPTION OF PREFERRED EMBODIMENT

Preferred embodiments will be described with reference to the accompanying drawings.

1. First Embodiment

1-1. Outline

FIG. **1** is a perspective view of a camera system according to the present embodiment. As shown in FIG. **1**, the camera system **1** includes a camera body **100** and an interchangeable lens **200**. The interchangeable lens **200** is provided with a zoom ring **213**. A user can manually perform a zoom operation by turning the zoom ring **213**.

The embodiment described below is made to provide a lens barrel capable of performing relatively rapid focus control upon zoom operation in the lens barrel capable of performing the manual zoom operation.

1-2. Configuration

FIG. **2** is a block diagram of the camera system **1**. A configuration of the camera system **1** according to the present embodiment will be described with reference to FIG. **2**.

1-2-1. Configuration of the Camera Body

The camera body **100** includes a CCD image sensor **110**, a liquid crystal device (LCD) monitor **120**, a camera controller **140**, a body mount **150**, a power supply **160**, and a card slot **170**.

The camera controller **140** controls the entire camera system **1**, including control of the CCD image sensor **110**, and the like, according to an instruction provided from an operating member such as a release button **130**. The camera controller **140** sends a vertical synchronizing signal to a timing generator **112**. In parallel with this, the camera controller **140** generates an exposure synchronizing signal based on the vertical synchronizing signal and periodically sends the generated exposure synchronizing signal to a lens controller **240** through the body mount **150** and a lens mount **250**. The camera controller **140** uses a DRAM **141** as a work memory for a control operation or image processing operation.

The CCD image sensor **110** captures a subject image incident thereon through the interchangeable lens **200** and generates an analog image signal. The generated analog image signal is converted to digital image data by an AD converter **111**. The image data converted by the AD converter **111** is subjected to various image processing by the camera controller **140**. The various image processing includes, for example, a gamma correction process, a white balance correction process, a flaw correction process, a YC conversion process, an electronic zoom process, and an image compression process such as a JPEG compression process.

The CCD image sensor **110** operates at a timing controlled by the timing generator **112**. The operations of the CCD image sensor **110** include a still image capturing operation, a moving image capturing operation, a through image capturing operation, and the like. The through image is an image that is not recorded in a memory card **171** after it is captured. The through image is mainly a moving image and is displayed on the LCD monitor **120** to be used for determination of a composition for capturing a still image.

The LCD monitor **120** displays an image represented by display image data subjected to image processing by the camera controller **140**. The LCD monitor **120** can selectively display a moving image or a still image.

The card slot **170** can be loaded with the memory card **171**. The card slot **170** controls the memory card **171** under control of the camera controller **140**. Specifically, image data generated by image processing of the camera controller **140** is stored in the memory card **171**. The memory card **171** can store various types of image files, for example, JPEG image file. Moreover, image data or image files stored in the memory card **171** can be read from the memory card **171**. Image data or an image file read from the memory card **171** is subjected to image processing by the camera controller **140**. For example, the camera controller **140** decompresses image data or an image file obtained from the memory card **171** to generate image data to be displayed.

The power supply **160** supplies power to be consumed in the camera system **1**. The power supply **160** may be, for example, a dry battery or rechargeable battery. Alternatively, the power supply **160** may supply the camera system **1** with power supplied from an external source through a power cord.

The body mount **150** can be mechanically and electrically connected to the lens mount **250** of the interchangeable lens **200**. The body mount **150** can send and receive data to and from the interchangeable lens **200** through the lens mount **250**. The body mount **150** sends an exposure synchronizing signal received from the camera controller **140** to the lens controller **240** through the lens mount **250**. The body mount **150** sends the other control signals received from the camera controller **140** to the lens controller **240** through the lens mount **250**. Moreover, the body mount **150** sends a signal received from the lens controller **240** through the lens mount **250** to the camera controller **140**.

1-2-2. Lens Barrel

1-2-2-1. Configuration of the Interchangeable Lens

The interchangeable lens **200** includes an optical system, the lens controller **240**, and the lens mount **250**. The optical system of the interchangeable lens **200** includes a zoom lens **210**, an OIS lens **220**, a diaphragm **260**, and a focus lens **230**.

The zoom lens **210** is a lens for changing a magnification of a subject image formed by the optical system of the interchangeable lens **200**. The zoom lens **210** includes one or a plurality of lenses. A drive mechanism **211** includes the zoom ring **213** operable by the user, and the like, and informs the zoom lens **210** of an operation performed by the user so that the zoom lens **210** is moved in an optical direction of the optical system. A detector **212** detects an amount of drive of the drive mechanism **211**. The detector **212** also detects a position of the zoom ring **213**, i.e., a position of the zoom lens **210** in a method described later. The lens controller **240** can recognize the zoom magnification of the optical system and the position, amount of turn, and turn speed of the zoom ring **213**, by obtaining detection results from the detector **212**.

The OIS lens **220** is a lens for correcting a blur of a subject image formed by the optical system of the interchangeable lens **200**. The OIS lens **220** reduces a blur of a subject image on the CCD image sensor **110** by moving in a direction to cancel a shake of the camera system **1**. The OIS lens **220** includes one or a plurality of lenses. An actuator **221** drives the OIS lens **220** in a plane perpendicular to the optical axis of the optical system under control of an OIS IC **223**. The actuator **221** can be implemented by, for example, a magnet and a planar coil. A position detection sensor **222** is a sensor that detects a position of the OIS lens **220** on the plane perpendicular to the optical axis of the optical system. The position detection sensor **222** can be implemented by, for example, a magnet and a Hall element. The OIS IC **223** controls the actuator **221** based on a detection result of the position detection sensor **222** and a detection result of a shake sensor such as a gyro sensor. The OIS IC **223** obtains a detection result of the shake sensor from the lens controller **240**. In addition, the OIS IC **223** sends a signal indicating a state of an optical image blur correction process to the lens controller **240**.

The diaphragm **260** is a member for regulating the amount of light passing through the optical system. The diaphragm **260** includes, for example, a plurality of diaphragm blades and can regulate the amount of light by opening and closing an opening formed by the blades. An iris motor **261** is drive means for opening and closing the opening of the diaphragm **260**.

The focus lens **230** is a lens for changing the focus state of a subject image formed on the CCD image sensor **110** by the optical system. The focus lens **230** includes one or a plurality of lenses.

A focus motor **233** drives the focus lens **230** to move the focus lens **230** back and forth along the optical axis of the optical system under control of the lens controller **240**. In this manner, the focus state of a subject image formed on the CCD image sensor **110** by the optical system can be changed. In the present embodiment, a stepping motor is used as the focus motor **233**. However, the focus motor **233** is not limited thereto but may be, for example, a DC motor or ultrasonic motor.

The lens controller **240** controls the entire interchangeable lens **200**, including control of the OIS IC **223** and the focus motor **233**, based on control signals from the camera controller **140**. For example, the lens controller **240** controls the focus motor **233** to move the focus lens **230** back and forth along the optical axis in a predetermined drive method, based on a control signal from the camera controller **140**. The lens controller **240** also receives signals from the detector **212**, the OIS IC **223**, and the like, and sends the signals to the camera controller **140**. The lens controller **240** sends and receives data to and from the camera controller **140** through the lens mount **250** and the body mount **150**.

The lens controller **240** uses a DRAM **241** as a work memory. A flash memory **242** stores a program and parameters used for control performed by the lens controller **240**. For example, the flash memory **242** stores information about a relationship between the position of the zoom lens **210** and the focus position of the focus lens **230** such as that shown in FIG. **4** described later, and the like.

1-2-2-2. Method for Detecting Turn speed of Zoom Ring

A method for detecting a turn speed of the zoom ring **213** will be described with reference to FIG. **3**. FIG. **3** is a diagram for describing the configuration and function of the zoom ring **213**.

The zoom ring **213** has, inside thereof, a slider **300**, a resistor **310**, and a cam groove which defines a path along which the slider **300** moves. When the zoom ring **213** is turned by the user, the slider **300** can move along the cam groove in a range of positions a and b, while electrically contacting with the resistor **310**. A voltage of 3.0 (V) is being applied across the resistor **310**. A voltage based on the position of the slider **300** on the resistor **310** is obtained from the slider **300**. That is, a voltage based on the position of the zoom ring **213** (i.e., the position of the zoom lens **210**) is obtained from the slider **300**. Thus, the detector **212** can detect a position of the zoom ring **213** (i.e., a position of the zoom lens **210**) as analog data by measuring a voltage of the slider **300**.

The lens controller **240** inputs as input a voltage detected by the detector **212** every predetermined period of time and processes digital data obtained by AD-converting the inputted voltage, thereby detecting a turn speed of the zoom ring **213**. The lens controller **240** provides **10** bits to detect a turn speed of the zoom ring **213**. In an example in FIG. **3**, a digital value corresponding to an analog voltage value detected from the slider **300** at the position a is 100 and a digital value corresponding to an analog voltage value detected from the slider **300** at the position b is 900. When a voltage measured by the slider **300** is 1.17 (V), the digital data corresponding to the voltage is 400. The unit of digital data after conversion is hereinafter referred to as "AD".

By thus detecting an amount of change, per unit of time, in digital data of a position of the zoom ring **213** which is detected by the detector **212**, the lens controller **240** can detect a turn speed of the zoom ring **213**. It should be noted that although in the camera system **1** according to the present embodiment a turn speed of the zoom ring **213** is calculated by detecting an amount of change per unit of time in the position of the zoom ring **213** (i.e., the position of the zoom lens **210**), the configuration does not necessarily need to be the one described above. For example, a turn speed of the zoom ring **213** may be directly detected.

1-2-2-3. Relationship Between Zoom Lens Position and Focus Lens Position

A relationship between the position of the zoom lens **210** and the focus position of the focus lens **230** will be described with reference to FIG. **4**. FIG. **4** is a schematic diagram for describing a relationship between the position of the zoom lens **210** and the focus position of the focus lens **230**.

The flash memory **242** stores relational information indicating a relationship between the position of the zoom lens **210** and the focus position of the focus lens **230**, such as that shown in FIG. **4**. The relational information includes a plurality of zoom tracking curves for respective distances to a subject (subject distances). In an example in FIG. **4**, the relational information includes four zoom tracking curves a, b, d, and e.

When the zoom lens **210** is driven in a focus state, the focus state is changed to an out-of-focus state on the CCD image sensor **110** if the focus lens **230** is left stopped. Hence, in the camera system **1** according to the present embodiment, upon driving the zoom lens **210** in a focus state, a zoom tracking curve associated with a subject distance is selected and the focus lens **230** is driven along the zoom tracking curve as the position of the zoom lens **210** changes. In this manner, even when the zoom lens **210** is driven, an image can be continuously captured with the focus state being maintained.

When a zoom tracking curve associated with a desired subject distance is not stored in the flash memory **242**, a position of the focus lens **230** for the desired subject distance is determined from zoom tracking curves for two subject distances close to the desired subject distance. For example, when the desired subject distance is between a subject distance associated with a zoom tracking curve b and a subject distance associated with a zoom tracking curve d, a virtual zoom tracking curve c is determined by interpolation from the zoom tracking curve b and the zoom tracking curve d. The focus lens **230** is driven along the virtual curve c. In this manner, even when a zoom tracking curve for a concerned subject distance is not stored in the flash memory **242**, a zoom tracking operation can be performed for any subject distance, enabling a zoom operation with a focus state being maintained.

1-2-3. Term Correspondence

The focus lens **230** is an example of a correction lens. The focus motor **233** is an example of a correction lens driver. A configuration including the slider **300**, the resistor **300**, and the lens controller **240** is an example of a position detector. The detector **212** and the lens controller **240** are an example of a rate detector. The drive mechanism **211** is an example of a zoom lens driver. The flash memory **242** is an example of a storage unit. The lens controller **240** is an example of a controller. The CCD image sensor **110** and the AD converter **111** are an example of an imaging unit. The camera controller **140** is an example of a recording unit. The memory card **171** is an example of a recording medium.

1-3. Zoom Tracking Operation in Manual Zoom

A zoom tracking operation conducted when a manual zoom operation is made by the user will be described with reference to FIGS. **5** and **6**A and **6**B. FIG. **5** is a flowchart for describing a zoom tracking operation conducted when a manual zoom operation is made. FIGS. **6**A and **6**B are schematic diagrams for describing the drive of the focus lens **230** conducted when a manual zoom operation is made.

The user can perform a manual zoom operation by turning the zoom ring **213**. The interchangeable lens (lens barrel) **200** according to the present embodiment mechanically drives the zoom lens **210**. Thus, when a manual zoom operation is done by the user with the zoom ring **213**, the zoom lens **210** is driven in response to the operation by the user. When a manual zoom operation is done (S**100**), the lens controller **240** inputs, as an input, information about the position of the zoom ring **213** from the detector **212** every predetermined detection period (in the present embodiment, the length of the detection period is 4 ms) to determine an amount of turn of the zoom ring **213**, and then determines whether the amount of turn is changed by an amount greater than or equal to a predetermined value (4 AD in this example) (S**110** and S**120**).

If it is determined that the amount of turn of the zoom ring **213** is greater than or equal to the predetermined value (4 AD), the lens controller **240** calculates a target position of the focus lens **230** based on the following equation (1) (S**130**). Specifically, the target position of the focus lens **230** is calculated in the following manner.

First, an increase Δd in the position of the zoom lens is obtained based on the equation (1).

$$\Delta d=\alpha+\beta\times(\Delta P)(AD) \tag{1}$$

In the equation (1), α is a constant and is set to 4 (AD), for example, which is equal to the predetermined value of the amount of turn of the zoom ring **213**. β is a coefficient and is set to 8, for example. α and β are appropriately determined through an experiment, or the like. ΔP is the amount of change (amount of turn) in the zoom ring position. It is assumed that the direction from a wide-angle end to a telephoto end of the lens is a positive direction. When ΔP is negative, an increase Δd in the zoom lens position is determined by the following equation.

$$\Delta d=-\alpha+\beta\times(\Delta P)(AD) \tag{1a}$$

Then, a corrected position of the zoom lens is determined by the following equation (1.1):

$$\text{Corrected position of zoom lens}=\text{currently detected position of zoom lens}+\Delta d(AD) \tag{1.1}$$

Thereafter, a position of the focus lens corresponding to the corrected position of the zoom lens is determined based on a zoom tracking curve shown in FIG. **4** and the determined position is used as a target position of the focus lens **230**.

When the target position of the focus lens **230** is calculated, the lens controller **240** controls the focus motor **233** to move the focus lens **230** to the target position (S**135**).

When the zoom lens **210** is stopped, as shown in FIG. **6**A, the focus lens **230** moves to a position corresponding to the current zoom lens position. On the other hand, when the zoom lens **210** is driven by a manual zoom operation by the user, as shown in FIG. **6**B, the focus lens **230** begins to move with a target position set to a focus position of the focus lens corresponding to a position distant from the current zoom lens position by the amount Δd calculated based on equation (1). For example, when $\alpha=4$, $\beta=8$, and the amount of turn (amount of change) of the zoom ring **213** is 8 AD, the increase Δd is calculated to 68 (=4+8×8) (AD) from the equation (1). Thus, the driving of the focus lens **230** is started with a target position set to a focus position of the focus lens **230** corresponding to a position of the zoom lens **210** distant from the current position of the zoom lens **210** by 68(AD) on the zoom tracking curve.

In this manner, when it is determined at step S**120** that the zoom ring position is changed by an amount greater than or equal to the predetermined value (4 AD), the lens controller **240** calculates a target position to which the focus lens **230** is moved, based on equation (1). The target position is set to a position more distant from the current position of the zoom lens **210** as the speed of a turn operation of the zoom ring **213** is higher. In other words, as the speed of a turn operation of the zoom ring **213** is higher, the focus lens **230** is driven to a focus position of the focus lens **230** corresponding to a position more distant from the current position of the zoom lens **210**. Therefore, the target position of the focus lens **230** can be changed according to the turn speed of the zoom ring **213**, that is, the change rate of the zoom ring position. As a result, even when the zoom lens **210** is changed at high speed, the focus lens **230** can be controlled to move to a more appropriate position along the zoom tracking curve so that accurate zoom tracking can be achieved according to the turn speed of the zoom ring **213**.

In this manner, while the zoom ring **213** is operated to turn, the focus lens **230** is driven with a target position set to a focus position of the focus lens **230** corresponding to a position distant by a predetermined amount from the current position of the zoom lens **210**. However, when the operation of turning the zoom ring **213** is stopped, the focus lens **230** is not driven to a position exceeding a focus position of the focus lens **230** corresponding to a stop position of the zoom lens **210**. This is because if the focus lens **230** is driven to a focus position of the focus lens **230** corresponding to a position distant from the stop position of the zoom lens **210** despite the stop of turning the zoom ring **213**, then an image captured by the COD image sensor **110** goes out of focus. Therefore, although driving of the focus lens **230** starts with a target position set to a focus position of the focus lens **230** corresponding to a position distant from the current position of the zoom lens **210**, the focus lens **230** does not overpass a focus position of the focus lens **230** corresponding to a position of the zoom lens **210** at the time.

The case will be described in which it is determined at step S**120** that the zoom ring **213** has not turned by an amount greater than or equal to the predetermined value (4 AD). In this case, the lens controller **240** determines whether the zoom ring **213** has turned in total by an amount greater than or equal to the predetermined value (4 AD) after the last drive of the focus lens **230** during the zoom tracking operation (S**140**).

If it is determined that the zoom ring **213** has not turned in total by an amount greater than or equal to the predetermined value (4 AD) after the last drive of the focus lens **230** during the zoom tracking operation, then the lens controller **240** returns to step S**110**.

If it is determined that the zoom ring **213** has turned in total by an amount greater than or equal to the predetermined value (4 AD) after the last drive of the focus lens **230** during the zoom tracking operation, then the lens controller **240** calculates a target position to which the focus lens **230** is moved, based on the following equation (2) (S**150**). Specifically, a target position of the focus lens **230** is calculated in the following manner.

First, an increase Δd in the position of the zoom lens **210** is determined based on the equation (2).

$$\Delta d=\alpha+\beta\times(\alpha/N+1)(AD)(\Delta d>0) \tag{2}$$

In the equation, α is a constant and is set to 4 (AD), for example, which is equal to the predetermined value of the amount of turn of the zoom ring **213**. β is a coefficient and is set to 8, for example. α and β are appropriately set based on an experiment, or the like. N is the number of detection periods during which the amount of change in the position of the zoom lens **210** has not exceeded the predetermined value.

Then, a corrected position of the zoom lens **210** is determined by the following equation (2.1).

$$\text{Corrected position of zoom lens}=\text{detected current position of zoom lens}+\Delta d(AD) \tag{2.1}$$

When it is determined that the zoom ring **213** has turned in total by an amount greater than or equal to the predetermined value (4 AD) in a negative direction after the last drive of the focus lens **230** during the zoom tracking operation, a corrected position of the zoom lens **210** is determined by the following equation.

$$\text{Corrected position of zoom lens}=\text{detected current position of zoom lens}-\Delta d(AD) \tag{2.1a}$$

Thereafter, the focus lens position corresponding to the corrected position of the zoom lens **210** is determined based on a zoom tracking curve shown in FIG. **4** and the determined position is used as a target position of the focus lens **230**. When the target position is calculated, the lens controller **240** controls the focus motor **233** to move the focus lens **230** toward the target position (S**155**).

As described above, when it is determined at step S**140** that the amount of change in total is greater than or equal to the predetermined value (4 AD), the lens controller **240** calculates the target position to which the focus lens **230** is moved, based on the equation (2). This arrangement allows the focus motor **233** to drive the focus lens **230** with a target position set to a focus position of the focus lens **230** corresponding to a position of the zoom lens **210** distant from the current position of the zoom lens **210**, even if a turn operation performed on the zoom ring **213** has a relatively low speed. Thus, the camera system **1** according to the present embodiment can provide highly accurate zoom tracking, even when a turn operation of the zoom ring **213** is performed at low speed. As a result, the camera system **1** according to the present embodiment can achieve relatively accurate zoom tracking according to the turn speed of the zoom ring **213**.

Although in the camera system **1** according to the present embodiment the drive of the focus lens **230** is changed according to the turn speed of the zoom ring **213**, the configuration does not necessarily need to be the one described above. For example, the drive of the focus lens **230** may be changed according to the change rate of the position of the zoom lens **210**. In short, it may be configured that information about change rate of the zoom lens position is outputted and the drive of the focus lens is controlled according to the output.

1-4. Summary of Present Embodiment

A lens barrel according to the present embodiment includes the focus lens **230** which is movable along the optical axis to perform zoom tracking, the focus motor **233** that drives the focus lens **230**, the zoom lens **210**, the zoom ring **213** that is turned by a ricer, the zoom lens drive mechanism **211** that mechanistically moves the zoom lens **210** according to the amount of turn of the zoom ring **213**, the slider **300** and resistor **310** (or the detector **212**) that detect a position of the zoom lens **210**, the detector **212** and lens controller **240** that detect a change rate of the zoom lens position, the flash memory **242** that stores relational information associating a position of the zoom lens **210** with a focus position of the focus lens **230**, and the lens controller **240** that controls the focus motor **233**. The lens controller **240** determines, by referring to the relational information, a focus position of the focus lens **230** corresponding to a position of the zoom lens **210** distant by a predetermined amount from the position of the zoom lens **210** detected by the slider **300** and the resistor **310**, and controls the focus motor **233** to drive the focus lens **230** with a target position set to the determined focus position. The lens controller **240** changes the predetermined amount according to the change rate of the zoom lens position detected by the detector **212** and lens controller **240**.

This configuration allows the focus motor **233** to drive the focus lens **230** with a target position set to a focus position of the focus lens **230** corresponding to a position more distant from the current position of the zoom lens **210** as the speed of a turn operation performed on the zoom ring **213** is higher. As a result, independent of the turn speed of the zoom ring **213**, deviation can be reduced between a focus lens position at the time drive of the focus lens **230** ends and a focus lens position on a zoom tracking curve corresponding to a new position of the zoom lens **210** at the time the drive of the focus lens **230** ends. Hence, focus control which is accurate and independent of the turn speed of the zoom ring **213** can be achieved.

In the lens barrel according to the present embodiment, the lens controller **240** varies an equation used to calculate the predetermined amount with the change rate of the zoom lens.

Accordingly, the lens controller **240** drives the focus lens **230** with a target position set to a focus position of the focus lens **230** corresponding to a position more distant from the current position of the zoom lens **210** as the speed of a turn operation performed on the zoom ring **213** is higher. As a result, the camera system **1** according to the present embodiment can achieve relatively rapid focus control according to the turn speed of the zoom ring **213**.

According to zoom tracking according to the present embodiment, even when the user changes a zoom magnification by operating the zoom ring **213** at a desired speed, a focus state can be kept. Therefore, the zoom tracking according to the present embodiment is particularly effective for shooting a moving image.

2. Other Embodiments

The first embodiment is described above. The embodiment is, however, not limited to that described above. Other embodiments will be described below.

The formation, value of constant and so on in the equations (1) and (1a) shown in the first embodiment are an example and, needless to say, other equations can be used as long as it is an equation by which an increase Δd that changes according to the change rate of the zoom lens position can be determined. Similarly, the formation, value of constant and so on in the equation (2) are an example and other equations can be used as long as it is an equation by which an increase Δd that slowly changes according to the zoom lens position which changes at low speed can be determined.

In the first embodiment, the equations (1) and (1a) may be further made to vary with the position of the zoom lens **210**. For example, the constant α and the coefficient β may be made to vary with the position of the zoom lens **210** such that Δd more greatly changes when the zoom lens **210** is at a telephoto end while Δd does not change much when the zoom lens **210** is at a wide-angle end. The same also applies to the equation (2).

Alternatively, the equation to calculate increase (correction amount) Δd in zoom lens **210** may be varied based on both the position of the zoom lens **210** and the position of the focus lens **230**. For example, as shown in FIG. **7**, a region indicated by the zoom lens position and the focus lens position may be divided into a plurality of regions, and the equation may be set independently for each divided region. For example, the constant α and the coefficient β in the equation (1) or the like may be made to vary such that Δd more greatly changes when the zoom lens **210** is on a telephoto side (zoom region NT-T) while Δd does not change much when the zoom lens **210** is on a wide-angle side (zoom region W-WN) and that, for the same zoom region, Δd more greatly changes as the position of the focus lens **230** is closer to the far side (distance region 2 m-infinity).

Although in the first embodiment a target position of the focus lens **230** in a zoom tracking operation is determined on the side of the interchangeable lens **200** based on a change rate of the position of the zoom lens **210** and the relational information, the target position may be determined on the side of the camera body **100**. In that case, the camera controller **140** receives in advance the relational information from the lens controller **240**. Then, during a manual zoom operation, the camera controller **140** periodically receives at least information about the position of the zoom lens **210** from the lens controller **240**, determines a target position of the focus lens **230** in the aforementioned method by referring to the received positional information, the relational information, and the like, and sends information about the determined target position to the lens controller **240**.

Although in the first embodiment the interchangeable lens **200** includes the flash memory **242**, the interchangeable lens **200** may include a ROM which is not writable instead of the flash memory **242**.

Moreover, although in the first embodiment the zoom tracking is achieved by driving the focus lens **230**, the focus lens **230** does not necessarily need to be used for the zoom tracking. For example, a correction lens dedicated to the zoom tracking may be additionally provided and the zoom tracking may be performed by driving the correction lens.

Although in the first embodiment the camera body **100** including no movable mirror is exemplified, the configuration of the camera body **100** is not limited thereto. For example, a movable mirror may be provided in the camera body **100** or a prism for splitting a subject image may be provided in the camera body **100**. Alternatively, a movable mirror may be provided not in the came body **100** but in an adapter.

Although in the first embodiment the CCD image sensor **110** is exemplified as an imaging device, the imaging device is not limited thereto. For example, the imaging device may be a CMOS image sensor or NMOS image sensor.

Moreover, although in the first embodiment the configuration in which a voltage of 3 V is applied across the resistor **310** is exemplified, the applied voltage is not limited to 3 V but may be 1 V or 5 V. That is, any voltage may be applied in accordance with application.

Although in the first embodiment the detection period of the amount of turn of the zoom ring **213** is 4 msec, the detection period is not limited thereto. For example, the detection period may be 2 msec, 8 msec, or 5 msec.

INDUSTRIAL APPLICABILITY

The present embodiment can be applied to a lens barrel used in a digital still camera, and the like.

Although the specified embodiment has been described as above, many other modifications, corrections and applications are apparent to those skilled in the art. Therefore, the present embodiment is not limited by the disclosure provided herein.

What is claimed is:

1. A lens barrel comprising:
a correction lens operable to move along an optical axis to perform zoom tracking;
a correction lens driver operable to drive the correction lens;
a zoom lens;
a zoom ring operable to be turned by a user;
a zoom lens driver operable to mechanically move the zoom lens according to an amount of turn of the zoom ring;
a position detector operable to detect a position of the zoom lens;
a rate detector operable to detect a change rate of the position of the zoom lens;
a storage unit operable to store relational information which associates the position of the zoom lens with a focus position of the correction lens; and
a controller operable to control the correction lens driver, wherein
the controller determines a focus position of the correction lens corresponding to a position more distant by a predetermined amount from the position of the zoom lens detected by the position detector, by referring to the relational information, and controls the correction lens driver to drive the correction lens with a target position set to the determined focus position,
the controller changes the predetermined amount according to the change rate of the position of the zoom lens detected by the rate detector,
further the controller uses a calculation formula which varies with the change rate of the zoom lens position to calculate the predetermined amount, and the calculation formula is set according to the position of the zoom lens and the position of a focus lens.

2. The lens barrel according to claim **1**, wherein the correction lens is the focus lens.

3. The lens barrel according to claim **1**, wherein the correction lens is a lens different from the focus lens.

4. An imaging apparatus comprising an interchangeable lens and a camera body to which the interchangeable lens is mountable, wherein
the interchangeable lens includes:
a correction lens operable to move along an optical axis to perform zoom tracking;
a correction lens driver operable to drive the correction lens;
a zoom lens;
a zoom ring operable to be turned by a user;
a zoom lens driver operable to mechanically move the zoom lens according to an amount of turn of the zoom ring;
a position detector operable to detect a position of the zoom lens;
a rate detector operable to detect a change rate of the position of the zoom lens;
a storage unit operable to store relational information which associates the position of the zoom lens with a focus position of the correction lens; and
a controller operable to control the correction lens driver,
the controller determines a focus position of the correction lens corresponding to a position more distant by a predetermined amount from the position of the zoom lens detected by the position detector, by referring to the relational information, and controls the correction lens driver to drive the correction lens with a target position set to the determined focus position, and the controller changes the predetermined amount according to the change rate of the position of the zoom lens detected by the rate detector,
the camera body includes:
an imaging unit operable to generate image data of a subject image captured through the interchangeable lens; and
a recording unit operable to perform a predetermined process on the image data and store the image subjected to the predetermined process in a recording medium,
further the controller uses a calculation formula which varies with the change rate of the zoom lens position to calculate the predetermined amount, and the calculation formula is set according to the position of the zoom lens and the position of a focus lens.

5. The imaging apparatus according to claim **4**, wherein the correction lens is the focus lens.

6. The lens barrel according to claim **4**, wherein the correction lens is a lens different from the focus lens.

7. An imaging apparatus comprising:
a correction lens operable to move along an optical axis for zoom tracking;
a correction lens driver operable to drive the correction lens;
a controller operable to control the correction lens driver;
a zoom lens;
a zoom ring operable to be turned by a user;
a zoom lens driver operable to mechanically move the zoom lens according to an amount of turn of the zoom ring;
a position detector operable to detect a position of the zoom lens;
a rate detector operable to detect a change rate of the position of the zoom lens;
a storage unit operable to store relational information which associates the position of the zoom lens with a focus position of the correction lens;
an imaging unit operable to generate image data of a subject image captured through the correction lens; and
a recording unit operable to perform a predetermined process on the image data and store the image subjected to the predetermined process in a recording medium,
wherein the controller determines a focus position of the correction lens corresponding to a position more distant by a predetermined amount from the position of the zoom lens detected by the position detector, by referring to the relational information, and controls the correction lens driver to drive the correction lens with a target position set to the determined focus position,
the controller changes the predetermined amount according to the change rate of the position of the zoom lens detected by the rate detector,
the controller uses a calculation formula which varies with the change rate of the zoom lens position to calculate the predetermined amount, and the calculation formula is set according to the position of the zoom lens and the position of a focus lens.

8. The imaging apparatus according to claim **7**, wherein the correction lens is the focus lens.

9. The imaging apparatus according to claim **7**, wherein the correction lens is a lens different from a focus lens.

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